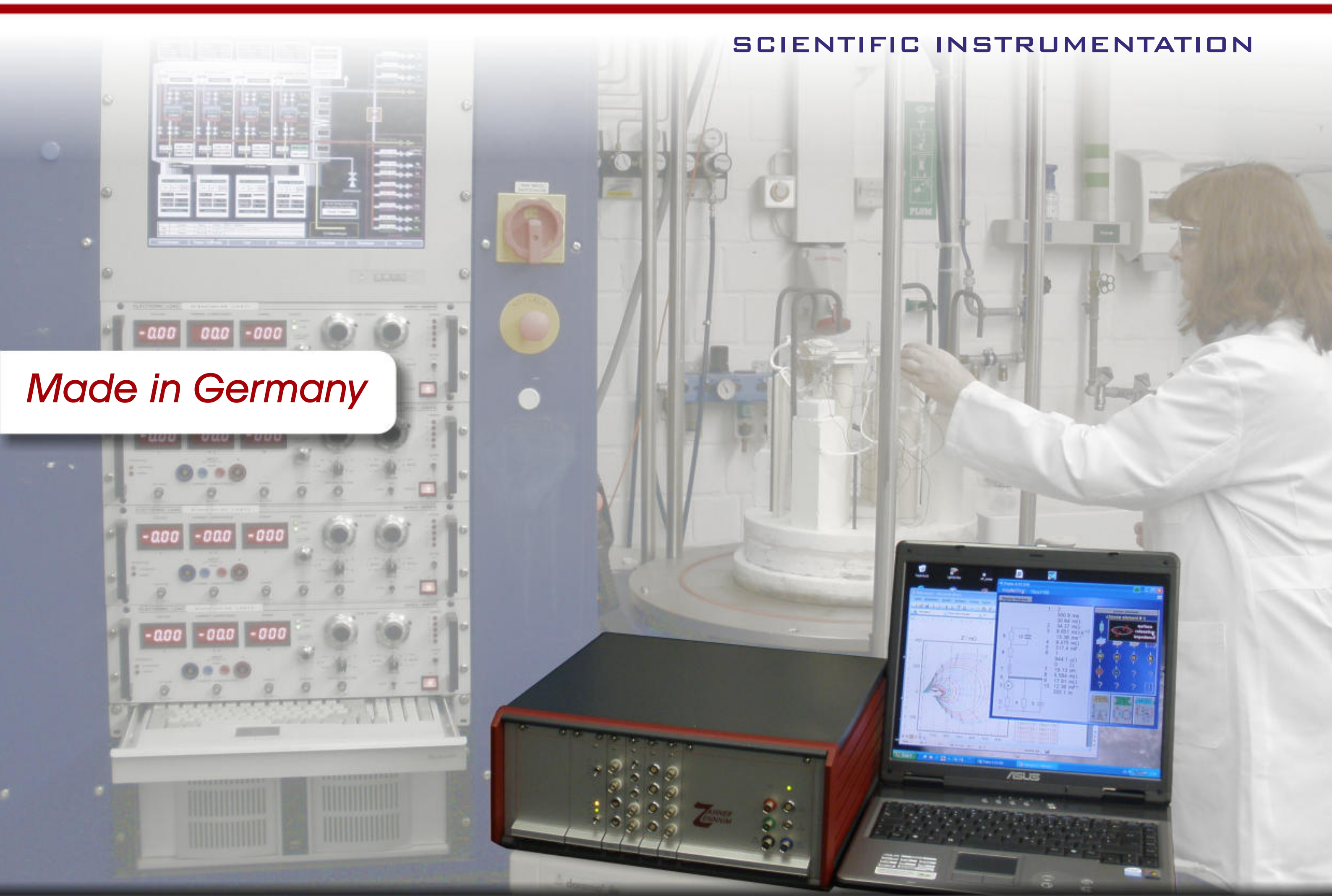
Highend Data Acquisition Systems

ZAHNER

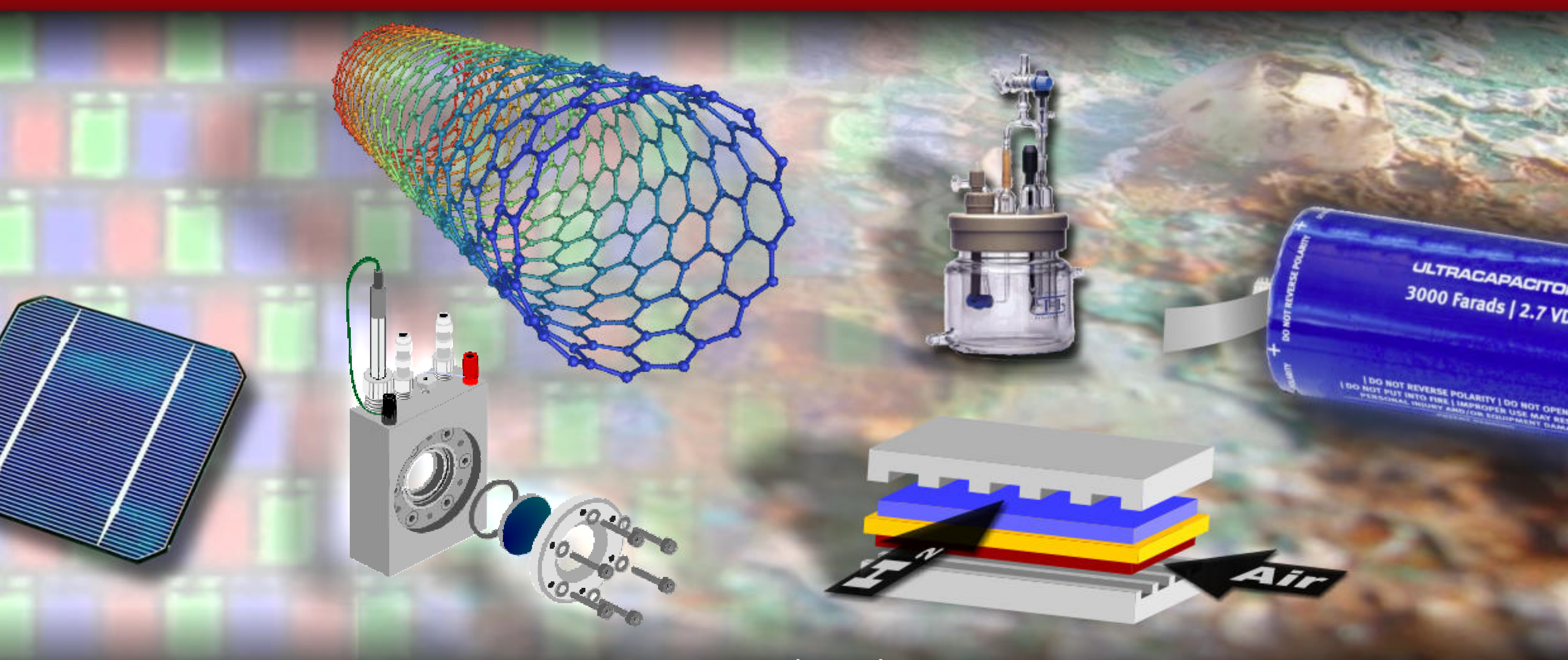
SCIENTIFIC INSTRUMENTATION



Made in Germany

Scientific Instrumentation

for Photons & Electrochemistry



www.zahner.de

ZAHNER ZENNIUM / IM6

electrochemical workstations

General

Our R&D team managed to create instruments with outstanding features, state-of-the-art hardware and an advanced software. The result is a milestone in scientific instrumentation. ZENNIUM and IM6 were developed using our 30 years of experience in producing high-precision electrochemical workstations of the high-end class. They provide a frequency range up to 4 MHz (ZENNIUM) / 8 MHz (IM6), an output current up to ±2.5 A (ZENNIUM) / ±3.0 A (IM6) and fast signal processing. Special measurement techniques guarantee an ultra high accuracy and a minimal interference with the test object.

ZENNIUM/IM6 come bundled with the outstanding THALES-Z (Zennium release) software package which offers all standard methods and more at a mouse click. This is why the ZENNIUM/IM6 can easily be adapted to very different measurement requirements. Furthermore, with the manifold options available, the ZENNIUM/IM6 is able to grow with its tasks. It is best suited for investigations on fuel cells, batteries and solar cells as well as on membranes and sensors or on coatings and laminates, to name only a few.

ZAHNER-elektrik is known to provide competent service all around the world. Our experienced specialists help you to plan, set up and analyze your experiments in electrochemistry, physics, material science and electronics.

Hardware

General

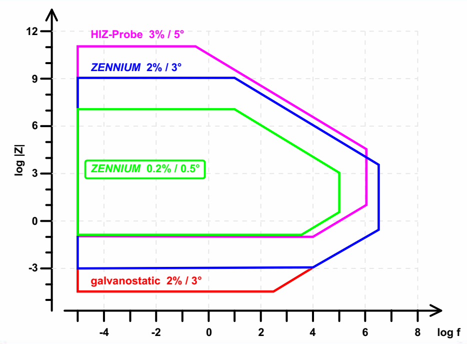
The hardware of the ZENNIUM/IM6 provides

- ultra low-noise potentiostat
- wide frequency range dual DDS FRA
- high CMRR precision U/I-amplifiers
- PulSAR® state-of-the-art differential 18 bit ADCs for AC
- connectors optimized for High Z & Low Z
- 4/9 extension card slots
- 410 MIPS (Dhrystone 2.1) V4e ColdFire® signal processor
- floating USB 2.0 interface

Accuracy

The highest priorities for the developement and production of the ZENNIUM instruments are accuracy and reliability. The accuracy map of the ZENNIUM clearly shows the high quality of the hardware. These specifications are proofed by measurements for practical use, based on the high-end components we use. They are not only calculated by the theoretical specifications of some components.

ZENNIUM accuracy map



Amplitude ≤ 10 mV.

Option	Function	ext	int	EPC42 needed
PAD4	4 channel parallel AD converter		X	
TEMP/U	2 inputs for thermocouples + 2 voltage inputs		X	
DA4	4 analog outputs		X	
RMux	Relay multiplexer for the internal potentiostat		X	
PwrMux	Power multiplexer for the PP series potentiostats	X	X	
TR8M	Transient recorder up to 40 MHz		X	
HiZ probe	High impedance probe set	X		
fF probe	Low capacitance probe set	X		
LoZ	Cable set for low impedances	X		
EPC42	Control module for up to 4 external potentiostats		X	
XPot	External standard potentiostat	X		X
PP series	External power potentiostats	X		X
EL series	External high current one quadrant potentiostats	X		X
NProbe	Probe set for measuring electrochemical noise	X		X
COLT	Set-up for coating and laminate testing	X		
CIMPS	Set-up for photo electrochemical applications	X		X
ElChem Cells	KMZ and AMZ type cells for various applications			

ZAHNER ZENNIUM / IM6

electrochemical workstations

The Modular System

... the only electrochemical workstation based on a universal modular data acquisition system

External Potentiostats and Electronic Loads

... enhance the output up to
±120 Volts
±40 Ampere
+600 Ampere (load)
50 000 Watt
64 Channels

NetVI Interface

... connect the Zennium/IM6 easily with external data acquisition & control devices over TCP/IP as virtual net instruments

Probes

... prepare the Zennium for special fields of application like high impedances, electrochemical noise, very low capacitance, etc. and interface with 3rd-party devices (electronic loads, potentiostats, ...)

Up to 9 Extension Card Slots

... expand your Zennium/IM6 optionally with plug & play cards for fast data acquisition and control output channels according to your special requests.

ethernet

ZAHNER ZENNIUM / IM6

THALES Z software package

Software

The powerful Thales software package is part of the standard equipment of each IM6 and ZENNIUM system. It provides a multitude of measuring and analysis methods.

The Thales software provides unique features for the acquisition and analysis. The most prominent examples are SCRIPT and SIM. SCRIPT offers you to program user defined combinations of all types of electrochemical measurements, mathematical analysis, algorithms, documentation and data export to a reproducible, fully automatic process. With the outstanding features of SIM you are able to create equivalent circuits and fit the measurement data to these models. The ZHIT feature of SIM helps you to validate your impedance spectra.

For evaluation only it is also possible to run Thales software package on a ThalesBox. The ThalesBox provides a single user licence of Thales. So you can process your recorded data on a simple PC or Laptop while your tests still run on the IM6 or ZENNIUM ...

- System requirements: IBM compatible PC
  Microsoft Windows XP / Vista / 7 / 8
  (32-bit / 64-bit)
  USB 2.0

General Fields of Application

- low impedance applications
  (fuel cells, batteries, super-caps ...)
- high impedance applications
  (coatings, laminates, membranes, sensors, corrosion ...)
- photoelectrochemical applications
  (silicon, dye-sensitized and organic solar cells, organic LED, semiconducting films ...)

Look & Feel

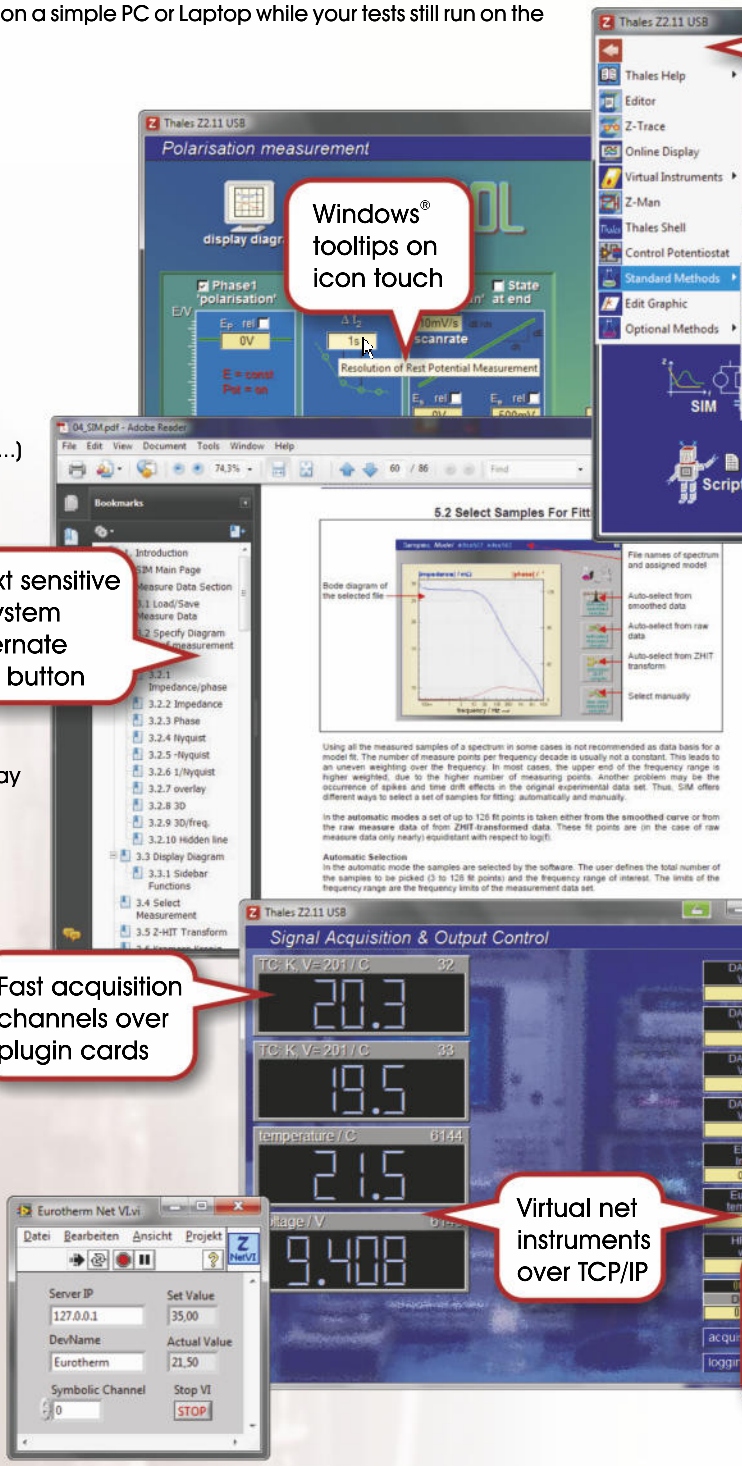
- electrochemical methods guide
- free scaleable application window
- Windows tooltips
- ThalesViewer (Windows Explorer extensions)
- fast online context sensitive help system
- icon navigation + direct access pull down menus
- child windows for configurable online measurement display

Special Functionalities

- fast multiple fitter for impedance and photovoltage /current spectra
- special modeling support for solar cells
- joint multiple transfer function fitting
- SCRIPT procedures for user-defined measurement, analysis- and documentation tasks
- multi-channel measuring data acquisition and control in parallel to the electrochemical experiments

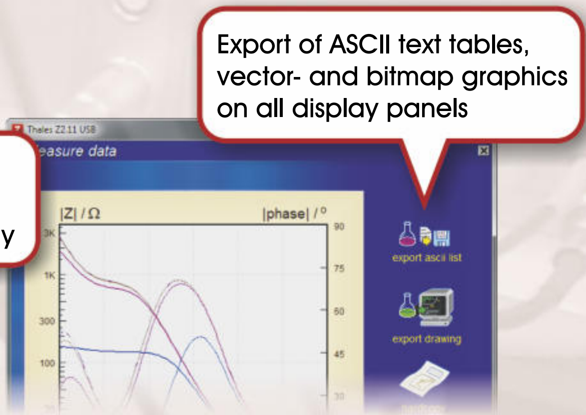
Connectivity

- remote control via LabVIEW VI
- integrate third-party signal acquisition devices over TCP/IP as NetVI
- ASCII data logging via online display



ZAHNER ZENNIUM / IM6

THALES Z software package



Supported Method	*Option**
Testsampling Online Display and Logging	-
Parallel Testsampling Online Display and Logging	PAD4
Electrochemical Impedance Spectroscopy	-
Parallel Electrochemical Impedance Spectroscopy	PAD4
EIS Series Measurements vs. Parameters	-
Impedance Network Analysis, Simulation & Fitting	-
Impedance/Parameter, Capacity/Voltage Curves	-
Parallel Impedance/Parameter, Capacity/Voltage Curves	PAD4
AC Voltammetry	-
Cyclic Voltammetry	-
Linear Sweep Voltammetry	-
Triangular Wave Voltammetry	-
Cyclic Triangular Wave Voltammetry	-
Chronoamperometry With Multiple Triangular Potential Sweeps	-
Stationary Electrode Voltammetry	-
Chronoamperometry With Linear Potential Sweep	-
Tafelscan	-
Steady State Current/Voltage Curves	-
Multi-Cell Current/Voltage Curves	XPOT, PP series
Corrosion / Polarisation Measurement	-
Potentiometry	-
Chronopotentiometry	-
Chronoamperometry	-
Pulse Plating	-
Universal Current/Potential/Time Curves	-
Time Domain Controlled Measurements	-
Electrochemical Noise	NProbe
CorrElNoise	NProbe
Tast Polarography	-
Differential Pulse Polarography	-
Differential Pulse Voltammetry	-
Stripping Voltammetry	-
Standard Addition Measurement & Analysis	-
Universal Measurement Data Acquisition & Control	NET*
Universal Frequency Response Analysis	-
AC-DC-AC Tests	COLT
Layer Quality Test / Bi-Layer Test	COLT
Fast Pulse & Transient Recording	TR8M
High Current Interrupt Measurements	HCI
Relaxation Voltammetry	NProbe
Solar Cell Fill-Factor, Efficiency, Maximum Power, OCP, ISC	CIMPS
Controlled Intensity Modulated Photocurrent Spectroscopy	CIMPS
Controlled Intensity Modulated Photovoltage Spectroscopy	CIMPS
Charge Extraction After N. W. Duffy, L. M. Peter et. al.	CIMPS
Light Transient Measurements. Chopped Light Voltammetry	CIMPS
DC vs. Intensity Transfer Functions, Time Domain Measurements	CIMPS
Lightemission Voltage/Current Characteristic (OPV)	CIMPS +
Spectral Resolved OPV, Absolute PL Quantum Yield	CIMPS +
Spectral Absorbtion Voltage/Current Characteristic	CIMPS +
Photocurrent Spectroscopy	CIMPS +
Quantum Efficiency, Incident Photon to Charge Carrier Efficiency	CIMPS +
Photocurrent/ -voltage Response on Fast Light Transients	CIMPS +
Dynamic and Static Transmittance / Reflectance	CIMPS +
Synchronous Multi Spectral DTR with Parallel Impedance	CIMPS +
Cross Transfer Function Measurements	-
Membrane Penetration Transfer Function Measurements	-
Programmable Procedures	-

***) Required hardware options**

ZAHNER ZENNIUM/ IM6

electronic load EL1000

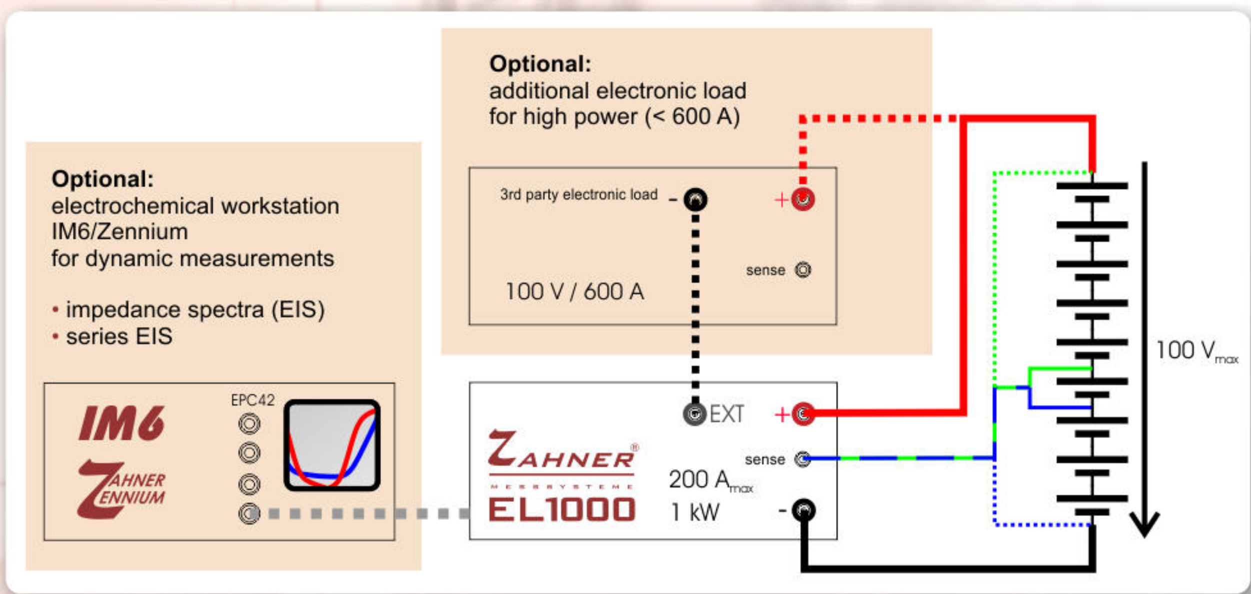
EL1000

Electronic Load El1000

Electronic loads are indispensable tools in several fields of electrochemistry, for example in the research of batteries and fuel cells. The EL 1000 was designed to investigate single cells as well as complete stacks, either as stand-alone device under PC control or in combination with a workstation IM6 or Zennium for instance for impedance measurements.
Adding an additional external electronic load, the power can be raised up – adding the PAD4 to the controlling workstation, individual segments of the stack can be investigated synchronously in parallel.

Specifications

Frequency range	10 µHz - 100 kHz
Current range	200 A / 600 A (with 3 party electronic load)
Voltage range	±4 V / ±100 V
Maximum power	1.000 W (stand-alone) scaleable with 3 party electronic load
Dimensions	470 x 160 x 446 mm



ZAHNER ZENNIUM / IM6

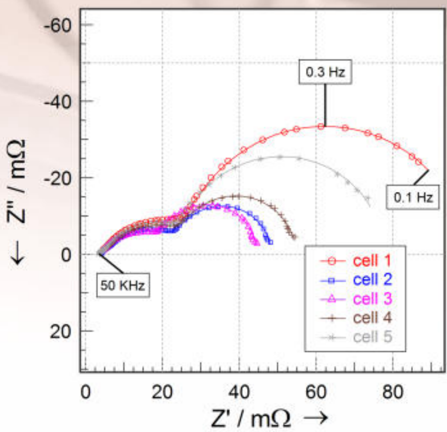
parallel impedance add-on

PAD4: 4 Channel Synchronous Impedance Converter

True Parallel Synchronous Impedance

Save time - measure up to 17 stack-cells in one run - no time mismatch between impedance spectra - record anodic, cathodic & total impedance simultaneously - measure additional transfer function signals...

The Zahner PAD4 is a 4-channel add-on card for Zahner Electrochemical Workstations. It introduces four additional parallel sampled signal inputs for cell voltage and impedance in fuel cell stacks and battery packs, with a common current. The Zahner Zennium supports up to two PAD4-cards for up to nine parallel channels, while the IM6 can control up to four cards for a maximum count of 17 parallel channels.
PAD4-cards are plug ‘n’ play – they are detected automatically on start-up. The PAD4 may be combined with the basic ECW or with the ECW controlling a slave potentiostat or an electronic load, finally providing tests on stacks of up to 100V / 600A / 50 KW.



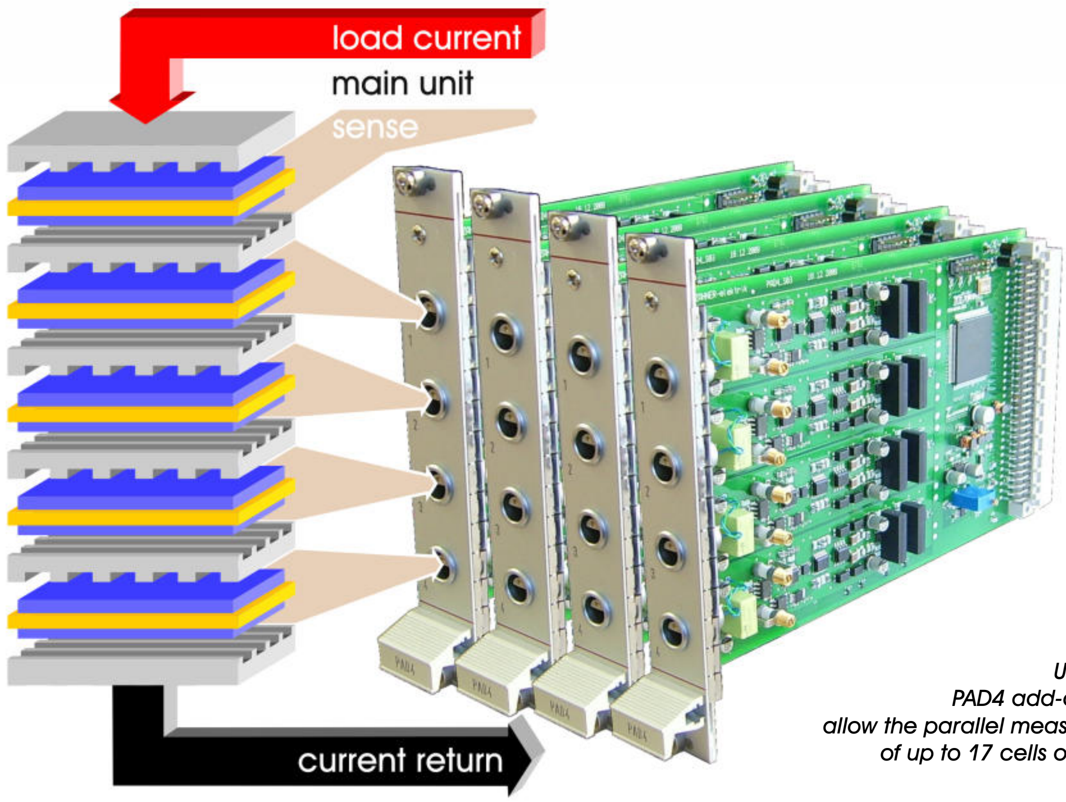
PAD4 Nyquist plot of a five cell SOFC stack

Additional Methods

- parallel electrochemical impedance spectroscopy
- parallel impedance/parameter capacitance/voltage curves
- parallel testsampling online display and logging

Specifications

Channels / card	4 individually addressable
Impedance measurement:	
Frequency range	10 μHz to 250 kHz
DC-potential measurement:	
Voltage range	±4 V
Common mode range	±100 V
A/D converter resolution	18 bit



Up to four PAD4 add-on cards allow the parallel measurement of up to 17 cells of a stack

ZAHNER ZENNIUM / IM6

low capacitance probe

fF-Probe: femto-Farad Probe

Low Capacitance Measurement Probe Set

The femto-Farad Probe works as a front-end to the IM6/Zennium potentiostat. Apart from its limited current capability, all basic functionalities of the Thales software are supported. In particular impedance spectroscopy can be applied. Due to the fact, that the primary measurement magnitude is the complex impedance, besides the sample capacity, resistive and DC contributions can be determined as well.

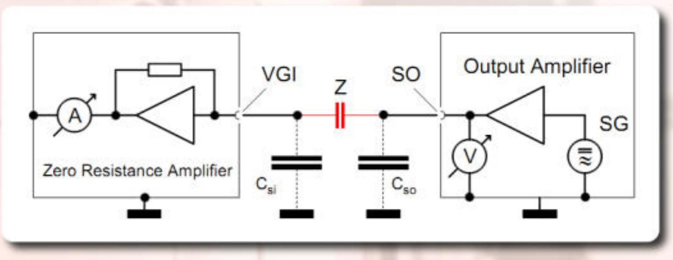
Additional Methods

- low capacitance electrochemical impedance spectroscopy
- low capacitance impedance/parameter

Specifications

Frequency range	10 μHz to 1 MHz
Current auto ranging, defeatable current ranges	0nA - $\pm$40 nA $\pm$40nA - $\pm$400 nA $\pm$400nA - $\pm$4 μA $\pm$4 μA - $\pm$40 μA
Voltage range	$\pm$4 V
Resolution of any range	18 bit
Capacity offset	$\pm$1 fF *)
Capacity resolution	$\pm$0,1 fF *)
Capacity accuracy	$\pm$0,25% of reading $\pm$2 fF *)

*) current range $\pm$40 nA, AC amplitude $\geq$ 100 mV, zero DC current

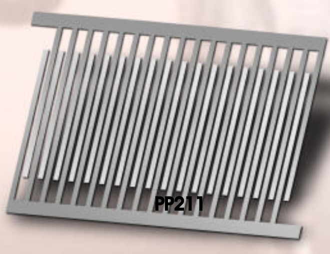


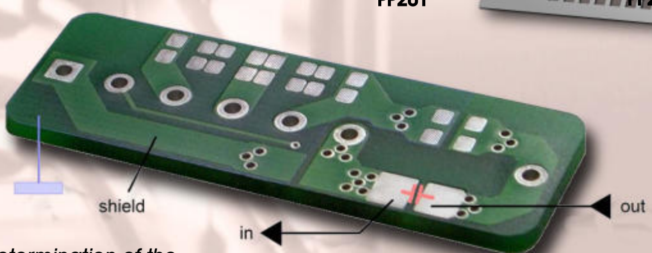
The trans-impedance principle for the determination of small capacities

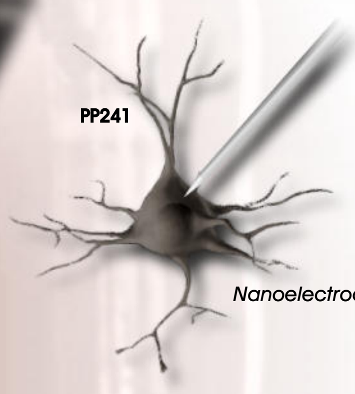
SO "hot" test signal output
VGI "virtual ground" signal input
Z device under test
V, A voltage and current measurement
C_{si} and C_{SO} parasitic stray capacitance at the input and output terminal

Microelectromechanical systems (MEMS) and Sensors

PP201 **PP211** **PP241**







Nanoelectrodes

Determination of the coupling capacity between two adjacent pads of a printed circuit board

ZAHNER ZENNIUM / IM6

PP-Series power potentiostats

PP2x1 Power Potentiostats

The PP-Series potentiostats are designed to apply and sink high currents up to ±40A at a total power dissipation of up to 200W.
The PP-Series potentiostats are controlled by an EPC42, a plug-in module for the Electrochemical Workstations IM6 and Zennium.

Up to four EPC42 cards can be installed in an IM6 or an Zennium. In total, up to 16 PPs can be controlled by one IM6/Zennium. Each potentiostat will hold the control parameters from one access to the next one, so that no potential or current disturbances can occur while scanning the potentiostats. If series measurements are performed with more than one PP-Series potentiostat, spectra are taken from all modules in a definable order.

The PP-Series is embedded completely in the IM6/Zennium environment. Thus, all acquisition and analysis techniques that run on the IM6/Zennium can be applied with the power potentiostats as well. The installation of one or more PP-Series potentiostat will upgrade your IM6/Zennium to an even more versatile, high-current electrochemical workstation.
The PP-Series potentiostats can also be controlled by a Windows®-PC. In this case they provide methods, summarized in the table below. They also work as a LabVIEW™ Virtual Instrument under the LabVIEW™ software. To implement the PP-Series potentiostats into existing test environment, a supporting DLL is available on demand.

You can control the PP-Series potentiostats in a mixed mode with an IM6/Zennium and a PC in parallel. Both devices can be connected and disconnected during operation.

Supported Methods with IM6/Zennium

- impedance spectroscopy
- simulation & model fitting
- cyclic voltammetry
- polarisation curves
- multicell multitasking voltammetry
- arbitrary current/potential/time measurements
- capacity/potential measurements
- automatic series measurements

Supported Methods with PC

- test sampling
- U vs. time, I vs. time
- current potential curves (U/I)
- cyclic voltammetry
- charging/discharging, battery cycling
- LabView® virtual instrument
- DLL support available

Specifications

Model name	PP201	PP211	PP241
Operating modes	pot/gal/oc	pot/gal/oc	pot/gal/oc
Potential range	±10 V	±20 V	±5 V
Potential accuracy	±0.1% / ±1 mV	±0.1% / ±2 mV	±0.1% / ±1 mV
Current range	0 A ... ±20 A	0 A ... ±10 A	0 A ... ±40 A
Current accuracy	±0.25% / ±1 mA	±0.25% / ±1 mA	±0.25% / ±1 mA
Output power	200 W	200 W	200 W
Frequency range	10 μHz - 200 KHz	10 μHz - 200 KHz	10 μHz - 200 KHz
Impedance range	1 μΩ - 1 KΩ	1 μΩ - 1 KΩ	1 μΩ - 1 KΩ
Ambient temperature	0 °C ... 30 °C	0 °C ... 30 °C	0 °C ... 30 °C
System requirements	IM6/Zennium+EPC42 or PC	IM6/Zennium+EPC42 or PC	IM6/Zennium+EPC42 or PC

ZAHNER ZENNIUM / IM6

specifications

General

General		Zennium	IM6
Overall Bandwidth		DC - 5 MHz	DC - 10 MHz
ADC Resolution		3 ADCs @ 18 bit	
Harmonic Reject		> 60 dB @ ½ full scale	
Potentiostat Modes		Potentiostatic, galvanostatic, pseudo-galvanostatic, rest potential, off, ZRA, FRA	
Cell Connection		2-, 3-, 4-terminal Kelvin	
Chassis		ground	
Extension Slots		4	9 (incl. 1x EPC42)
PC interface		USB 2.0	
Dimensions		364 x 160 x 376 mm	470 x 160 x 376 mm
Weight		12 kg	15 kg
Accessories		U-buffer, 2 cell cable set, USB-cable, power cord, manual	+Thalesbox, +EPC42
Power supply		230/115 V, 50/60 Hz	
Ambient temperature		+10° C to +30° C	
Ambient Humidity		< 60% without derating	

Frequency Generator & Analyzer

Frequency Range		10 µHz to 4 MHz	10 µHz to 8 MHz
Accuracy		< 0.0025%	
Resolution		0.0025%, 10.000 steps/decade	

Output Potentiostatic

Full Scale Voltage		±4 V (Main), ±10 V (U-buffer)	
Resolution		125 µV (Main), 320 µV (U-buffer)	
Accuracy		±250 µV ±0.025% of set voltage (Main), ±2 mV ±0.025% of set voltage (U-buffer)	
Temperature Stability		better 20 µV/°C	
Compliance Voltage		±14 V (Main), ±120 V (with CVB120)	
AC-Amplitude		1 mV to 1 V (Main), 1 mV to 25 V (CVB120)	
Bandwidth		4 MHz @ 33 Ω load	8 MHz @ 33 Ω load
IR Compensation	Method	Auto AC Impedance Technique	
	Range	0 to 10 MΩ	
	Resolution	0.012%	
Small Signal Rise Time		250 ns to 200 µs in 5 steps, automatic selection by automatic stability control	
Slew Rate		15 MV/s	
Phase Shift		10° @ 250 kHz	

Output Galvanostatic

Full Scale Current Ranges	Main	±100 nA to ±2.5 A in 10 steps	±100 nA to ±3.0 A in 10 steps
		resolution 0.0031% (16 bit) of range	
		lowest full scale range ±100 nA, resolution 12.5 pA	
	HiZ	±1 nA to ±0.5 A in 12 steps	
		resolution 0.0031% (16 bit) of range	
		lowest full scale range ±1 nA, resolution 125 fA	
Accuracy **	Main	±0.1% of set value @ > |2 µA| to |100 mA|	
		±1% of set value @ |1 nA| to |2 µA| or > |100 mA|	
		±1% of set value, ±20 pA @ <|1 nA|	
	HiZ	±1% of set value, ±250 fA @ <|1 nA|	

Input

Full Scale Potential Ranges		±1, ±2, ±4 V (Main), ±4, ±10 V (U-buffer)	
Potential Resolution DC *		0.0008% / 32 µV (Main) / 80 µV (U-buffer)	
Potential Resolution AC *		16 nV	
Potential Accuracy DC **		±0.025% of reading ±0.25 mV (Main) ±1 mV (U-buffer)	
Offset Temperature Stability		< 10 µV/°C	
Full Scale Current Ranges *	Main	±100 pA to ± 2.5 A in 33 steps	±100 pA to ± 3.0 A in 33 steps
		automatic range selection	
	HiZ	±1 pA to ±0.5 A in 35 steps, automatic range selection	
Current Accuracy DC **	Main	±0.05% of reading @ > |2 µA| to |100 mA|	
		±0.5% of reading @ < |2 µA| or > |100 mA|	
		±0.5% of reading, ±10 pA @ < |1 nA|	
	HiZ	±0.5% of reading, ±125 fA @ < |1 nA|	
Input Bias Current **	Main	|±1 pA| (typ.) / |±5 pA| (max.)	
	HiZ	|±10 fA| (typ.) / |±125 fA| (max.)	
Current Resolution DC *	Pot	2.5 pA	
	HiZ	25 fA	
Current Resolution AC *	Pot	1.6 fA	
	HiZ	16 aA	
Input Impedance	Main	10 TΩ // ±5 pF (typ.)	
	HiZ	1000 TΩ // ±1 pF (typ.)	
Impedance Range	Main	100 mΩ to 10 MΩ / 0.2%	
	Potentiostatic	1 mΩ to 1 GΩ / 2%	
	Galvanostatic	30 µΩ to 1 GΩ / 2%	
	HiZ	100 mΩ to 100 GΩ / 3%	
Common Mode Rejection		> 86 dB @ 10 µHz to 100 kHz	
		> 66 dB @ 100 kHz to 4 MHz	> 66 dB @ 100 kHz to 8 MHz
Input Channel Phase-		±0.1° @ 10 µHz to 100 kHz	
Tracking accuracy		±0.25° @ 100 kHz to 4 MHz	±0.25° @ 100 kHz to 8 MHz
Equiv. Effective Input Noise	Main	2 µV rms / 200 fA rms @ 1 mHz to 10 Hz	
	HiZ	20 µV rms / 30 fA rms @ 1 mHz to 10 Hz	

* Guaranteed by design. For details refer to http://www.zahner.de application note "how to read specifications"

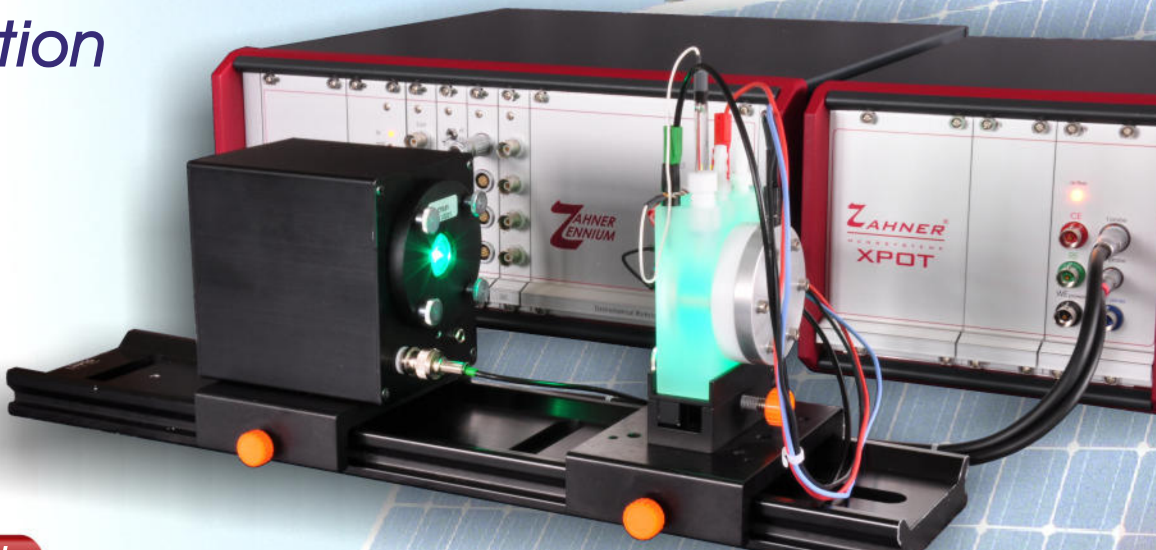
** In the first 6 months after factory calibration, after 20 min. warm-up

ZAHNER CIMPS

photoelectrochemical workstation

universal photo- & spectro-electrochemical workstation

CIMPS



Your Application Fields

photo-electrochemical energy conversion
semiconductors
monolithic solar cells
organic solar cells
dye-sensitized solar cells
hybride solar cells

LEDs
OLEDs
electronic displays
electronic newspaper
electrophoretic ink

electrochromic devices
smart windows
electrochromic glass
intelligent dimming mirrors
suspended particle devices
polymer dispersed liquid crystal devices

solar induced photo-electrochemical ...
... hydrogen production
... waste decontamination
... fuel production
... CO_2 reduction

artifical photosynthesis
...

Our Tools

CIMPS / IMPS
CIMVS / IMVS
Fast Intensity Transients
Absorption Spectroscopy
Emission Spectroscopy
DC Characteristic
C-V Measurement
AC Impedance
Charge Extraction
Long Term Stability
Standard SC Characterization
Dynamic Transmission / Reflection
(OIS Optical Impedance Spec.)
EQE Measurement
PV Conversion Efficiency
Photocurrent Spectroscopy
Chopped Light Voltammetry

Photo-electrochemical Transfer Functions
Impedance Simulation & Fitting
Photocurrent Simulation & Fitting
Photovoltage Simulation & Fitting

Joint Fit of Impedance, Photovoltage and Photocurrent Spectra (TRIFIT)

Your Results

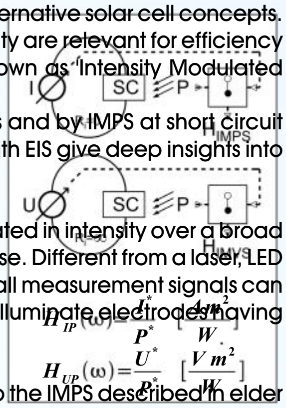
mechanisms
kinetics
charge carrier mobility
total conversion efficiency
spectral efficiency
charge carrier ...
... lifetime
... recombination time
... diffusion rate
solar cell ...
... serial resistance
... shunt resistance
... maximum power
... fill factor
... V_{OC}, J_{SC}
... IPCE
... stability
... external quantum efficiency
semiconductor permittivity
doping density
spectral emission
integral emission power
display transition time
transmission/reflection DC characteristic

ZAHNER CIMPS

photo-electrochemical system

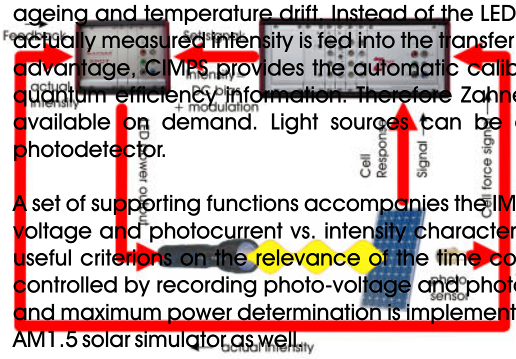
General

CIMPS is a photo-electrochemical research system for a wide field of applications. It is based on our universal electrochemical workstations Zennium or IM6, extended by special hard- and software. The basic configuration was designed with focus on static and dynamic photo-electrochemical transfer function measurement, popular in the research of alternative solar cell concepts. In particular, the dynamic transfer functions between photovoltage or photocurrent and light intensity are relevant for efficiency considerations of dye-sensitized oxide solar cells and organic solar cells. These functions are known as 'Intensity Modulated Photocurrent Spectroscopy' IMPS and 'Intensity Modulated Photo-Voltage Spectroscopy' IMVS.
Usually one is interested in the dominating time constants found by IMVS at open circuit conditions and by IMPS at short circuit conditions. Beyond this, thorough analysis and simulation of the transfer functions in combination with EIS give deep insights into the cell under test and the working mechanisms in detail.



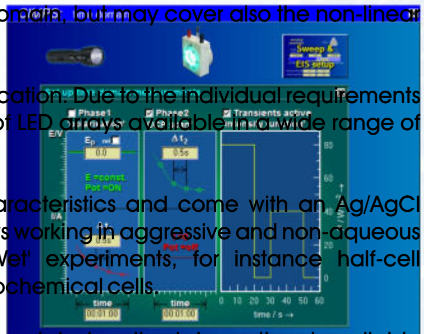
IMPS and IMVS are determined in the frequency domain by means of a light source, which is modulated in intensity over a broad frequency range, analogous to the EIS principle. CIMPS uses light emitting diodes 'LED' for that purpose. Different from a laser, LED do not need high modulation energy, and artifacts due to the presence of high voltage close to small measurement signals can be avoided. There is also no need for expander lenses, which must be inserted into a laser beam to illuminate electrodes having typical areas of up to several square centimetres.

CIMPS is the first complete system on the market designed especially for that purpose. Compared to the IMPS described in elder literature, important improvements were made by Zahner: a control loop regulates light intensity and modulation keeping it absolutely stable. The automatic comparison between set value and sensed intensity eliminates the influence of non-linearity, ageing and temperature drift. Instead of the LED supply current, used as a substitute magnitude in the traditional set-up, the actually measured intensity is fed into the transfer function calculation, avoiding scale- and phase shift errors. As an additional advantage, CIMPS provides the automatic calibration of the illumination in natural units of intensity (W/m), allowing instant quantum efficiency information. Therefore Zahner light sources are shipped with NIST traceable calibration. A certificate is available on demand. Light sources can be calibrated also on user site with an optionally available NIST traceable photodetector.



A set of supporting functions accompanies the IMPS and IMVS feature, useful for solar cell analysis as well. The static DC-photo-voltage and photocurrent vs. intensity characteristic can be determined. Among other value, the static behaviour provides useful criterions on the relevance of the time constants, derived by IMPS / IMVS. Stability and degradation of a SC may be controlled by recording photo-voltage and photocurrent vs. time at a constant intensity. SC efficiency, fill factor, integral IPCE and maximum power determination is implemented as a standard push button function, which works together with a 3rd-party AM1.5 solar simulator as well.

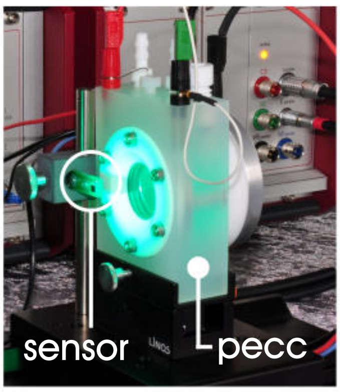
While IMPS / IMVS are typical small signal linear frequency domain techniques. CIMPS also provides light transient experiments. They can be used in order to cross-check the frequency domain results in the time domain, but may cover also the non-linear regimes.



The CIMPS standard package consists of all components necessary for the core application. Due to the individual requirements of the user, light sources have to be ordered separately. Please ask for our latest list of LED arrays available in a wide range of wavelengths and for tuneable light sources.

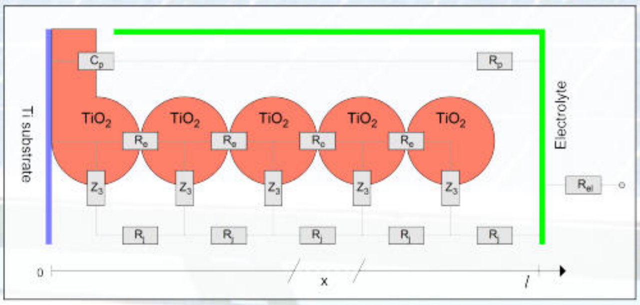
The Zahner PECC cells are optimized for perfect optical as well as electrical characteristics and come with an Ag/AgCl reference electrode and a Pt counter electrode coil. The PTFE/PCTFE-based solid allows working in aggressive and non-aqueous electrolytes. A gas-tight version, allowing oxygen-free working is available. 'Wet' experiments, for instance half-cell measurements, can be performed perfectly in these specially designed photo-electrochemical cells.

Apart from the core application, the CIMPS system may be extended to many other related methods by optional available peripherals. Certain 3rd-party spectrometers can be

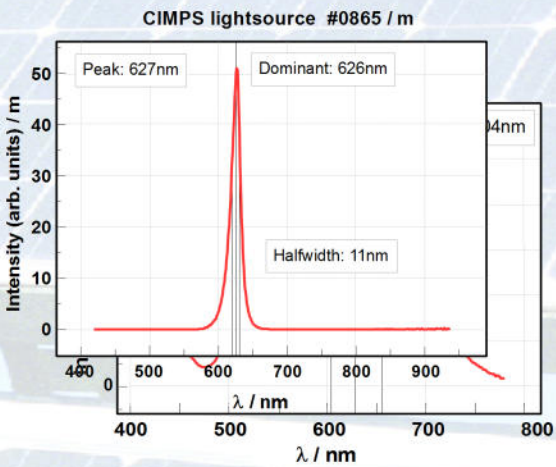


connected directly. CIMPS is able to control these spectrometers and provides spectral resolved lightemission (OPV) measurements, valuable for instance in OLED research and testing. The CIMPS-abs option may be used for spectral resolved absorption measurements, necessary for the investigation of electro-chromic processes and materials for electronic displays, OLED and organic solar cells.
CIMPS-pcs is based on our special tuneable lightsources. It opens the door to traditional photocurrent-spectroscopy PCS, spectral resolved incident photon conversion efficiency and the whole set of related spectro-electrochemical techniques. Finally, the FRA of the CIMPS system can be configured to a lock-in mode, which allows CIMPS to work together with 3rd-party chopper / monochromator units.

The components of the CIMPS package are working together in a plug & play application, including the software and an overall calibration of the system. An Electrochemical Workstation (ECW) IM6 or Zennium operates as a Frequency Response Analyser and as a support unit (Potentiostat / Galvanostat) for the cell under test. The Zahner ECWs are renowned for their high precision, ease of use and comprehensive software. One may select between two slave potentiostats (XPOT, PP211) used for the control of the light source, which differ in the output power to cover low-noise as well as high intensity applications.
The light source carrier including a fast high precision low noise photo-amplifier is positioned on an optical bench face to face with the photo-electrochemical cell. A photodiode sensor is mounted close to the cell's light inlet.

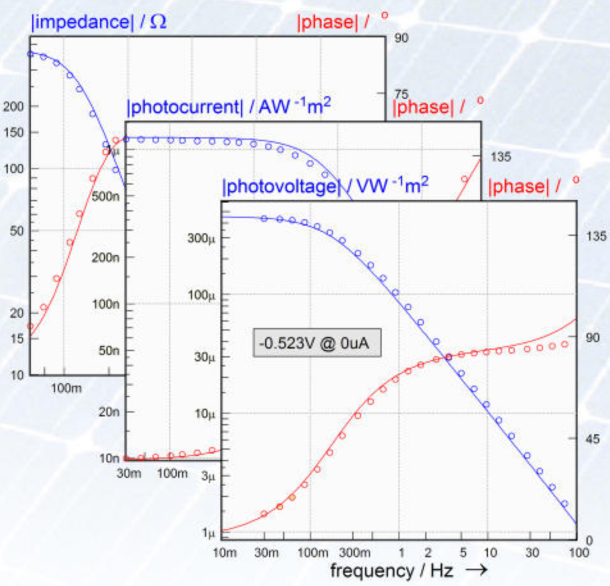


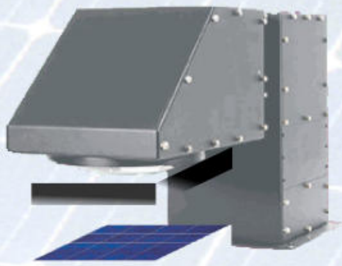
modelling photo-electrochemical systems



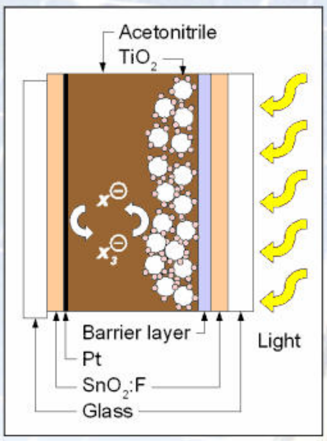
fully specified calibrated lightsources

TRIFIT: joint model simulation and fitting of impedance, photocurrent (IMPS) and photovoltage (IMVS) spectra





solar simulator support



ZAHNER CIMPS

optical methods ...

Functions

P:	Luminous intensity [W/cm²]
U:	Photo voltage [V]
I:	Photo current [A]
E:	Light source potentiostat set voltage [V]
Q:	Charge [C]
U_{OSC}:	Open circuit voltage [V]
I_{SC}:	Short circuit current [A]
N_{max}:	Electrical power [W] at the point of the maximal product $U{\cdot}I$ of the solar cell current voltage curve
n_e:	number of photoelectrons
n_{ph}:	number of incident photons
^:	amplitude symbol
ω:	angular frequency [Hz]
φ:	phase shift [rad]
j:	imaginary unit
$rect_p$:	periodic squarewave function

Standard Solar Cell Tests

- maximum power $N_{max}(P)$
- fill factor $FF = \frac{N_{max}}{U_{OCP} \cdot I_{SC}}$
- efficiency $\eta = \frac{N_{max}}{P}$
- IPCE $IPCE = \frac{n_e}{n_{ph}}$

Static Photo-Electric Transfer Functions

- static photovoltage vs. intensity curve $F_{UP} = U(P)$
- static photocurrent vs. intensity curve $F_{IP} = I(P)$
- static photocurrent vs. cellvoltage at constant intensity $F_{IU} = I(U)_P$

Dynamic Photo-Electric Transfer Functions

- dynamic photovoltage efficiency IMVS $H_{UP}(\omega) = \frac{U(t)}{P(t)}$ with $U(t) = \hat{U} \cdot e^{j\omega t + \varphi_U}$, $P(t) = \hat{P} \cdot e^{j\omega t}$
- dynamic photocurrent efficiency IMPS $H_{IP}(\omega) = \frac{I(t)}{P(t)}$ with $I(t) = \hat{I} \cdot e^{j\omega t + \varphi_I}$, $P(t) = \hat{P} \cdot e^{j\omega t}$

Time Domain Measurements

- photovoltage vs. time at constant intensity $U(t)$
- photocurrent vs. time at constant intensity $I(t)$

Intensity Transients Measurements

- photovoltage vs. time under intensity transients $U(t, P)$
- photocurrent vs. time under intensity transients $I(t, P)$

Charge Extraction after N. W. Duffy, L. M. Peter et. al.

$Q(t)$

Chopped Light Voltammetry

$I(U, P \cdot rect_p(t))$

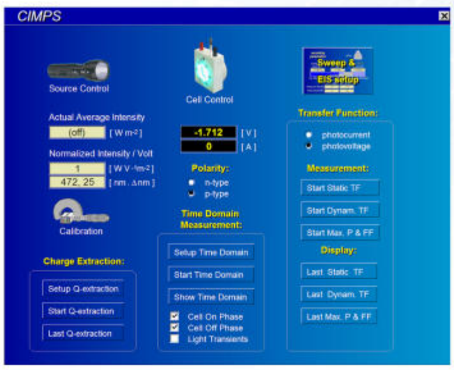
Calibration Routines for LED & OLED

- dynamic lightsource efficiency $H_{EP}(\omega) = \frac{P(t)}{E(t)}$ with $P(t) = \hat{P} \cdot e^{j\omega t + \varphi_P}$, $E(t) = E \cdot e^{j\omega t}$

Electrochemical Methods & Utilities

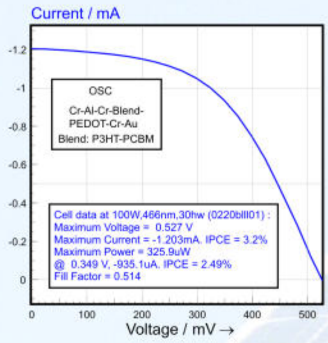
- electrochemical impedance spectroscopy (EIS)
- impedance & network analysis, simulation & fitting
- EIS series vs. parameter (time, potential, current, temperature, pH ...)
- impedance vs. parameter (time, potential, current, temperature, pH ...)
- stationary current / voltage characteristics & polarisation measurements
- cyclic & linear sweep voltammetry
- graphic, documentation & programming utilities
- ...

Please refer to the ZENNIUM® brochure for a complete list of methods

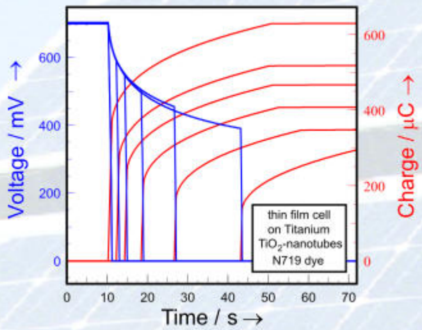


ZAHNER CIMPS

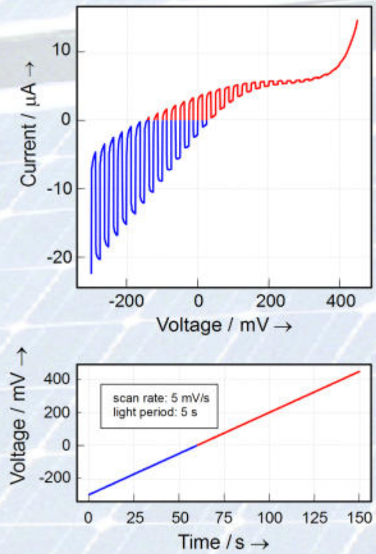
... and results



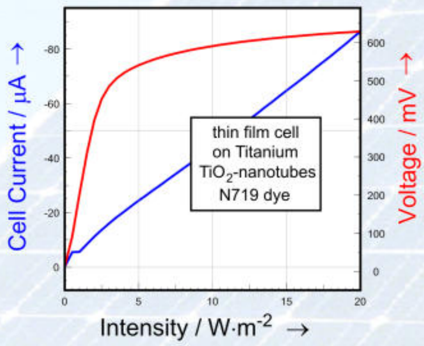
SC Fill-Factor, IPCE and Maximum Power



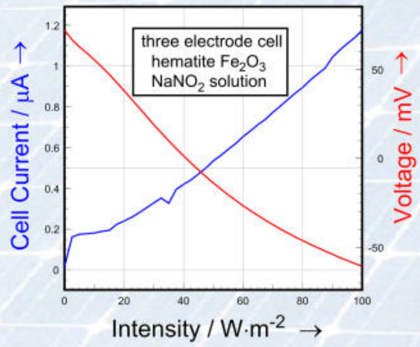
DSSC Charge Extraction after L.M. Peter



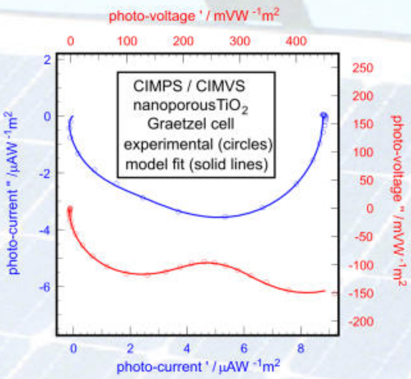
Chopped Light Voltammetry
P3HT-PEDOT:PSS in Acetonitrile TBA-PF_6



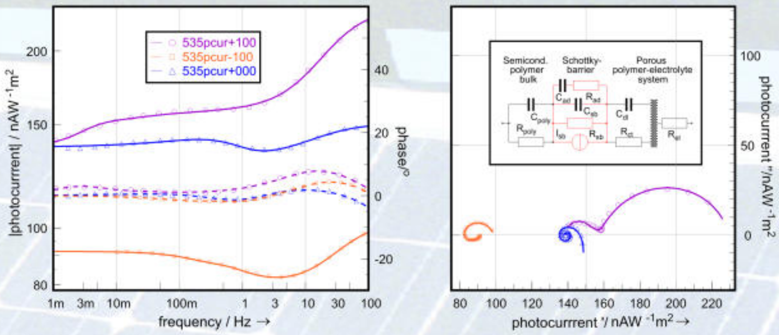
DSSC DC vs. Intensity Transfer Function



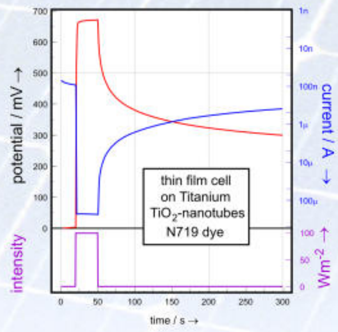
Alternative SC DC vs. Intensity Transfer Function



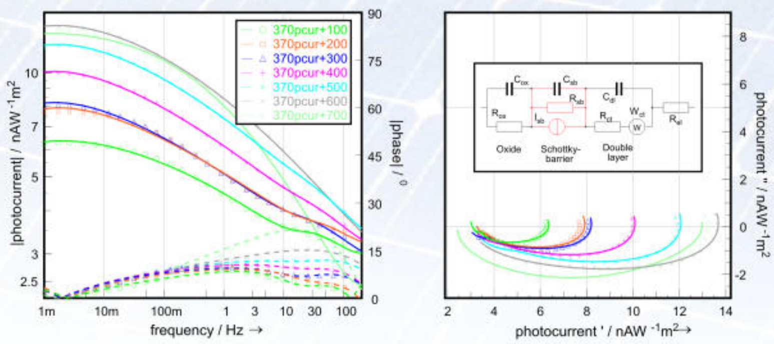
DSSC IMPS/IMVS Experimental
Data, Simulation and Fit



Hybrid SC IMPS/IMVS Experimental Data, Simulation and Fit



DSSC Light Transient



SC IMPS/IMVS Experimental Data, Simulation and Fit

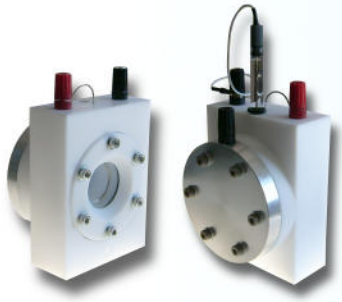
ZAHNER CIMPS

photo-electrochemical cells and light sources

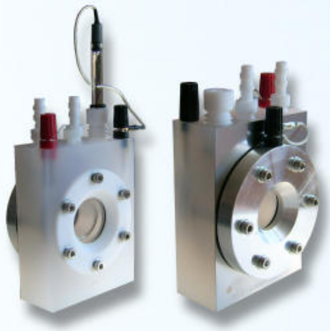
Photo-electrochemical Cells

PECC-1 / PECC-2

The PECC-1/PECC-2 are specially tailored for testing electrode materials with photo-electrochemical techniques. Several mounting options for samples offer flexibility for various tasks.



PECC-1



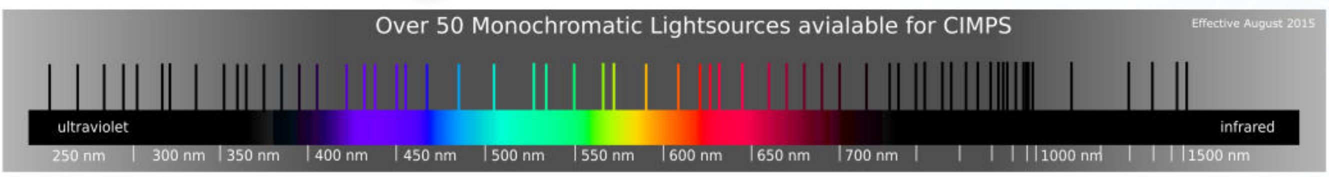
PECC-2
(shown with transparent WE)

Specifications	PECC-1	PECC-2
Physical dimensions (W x D x H)	60 x 25 x 80 mm	60 x 25 x 80 mm
Optical window diameter	20 mm	18 mm
Optical window material	BK7 or Quartz	BK7 or Quartz
Sample diameter	max. 20 mm	max. 18 mm
	25 - 40 mm	25 - 40 mm
		< 25 mm on request
Electrolyte volume	7.9 cm	7.2 cm
	6.3 cm	5.9 cm
Light path length in electrolyte	18 mm	18 mm
	23 mm	23 mm
Solid material	Teflon (PTFE)	Kel-F (PCTFE)
Reference electrode	Ag/AgCl	Ag/AgCl
Counter electrode	Pt coil	Pt coil
Gas inlet/outlet	No	Yes

sample in electrolyte chamber
sample as rear tightening plate

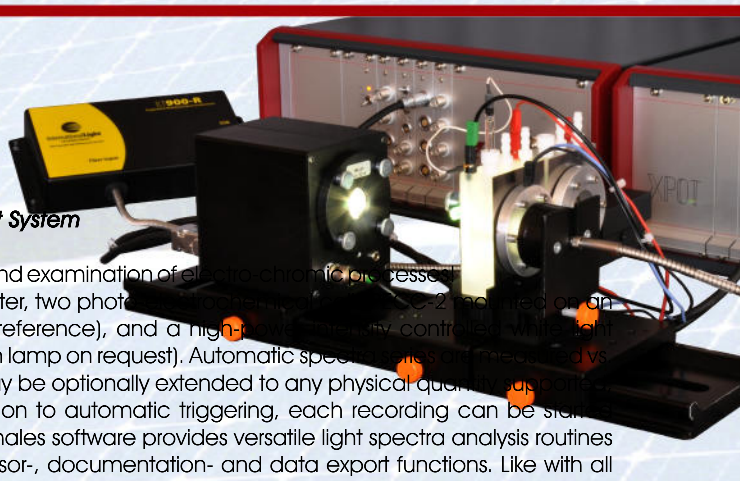
Light Sources

More than 50 monochromatic light sources from UV to IR are available for the CIMPS system. They are supplemented by high power white LEDs (up to 2000 W/m^2), tungsten lamps and tuneable light sources. Apart from recording photocurrent spectra, the tuneable light source TLS03 can also be used for standard methods supplied by the CIMPS system.
All LED light sources are calibrated traceable to the national metrology institute of germany PTB. Identification of the light sources and setting of the individual calibration data is performed by the CIMPS system automatically. So, exchanging light sources is plug and play.



ZAHNER CIMPS

spectro-electrochemical option abs



Absorption: abs

Spectral Resolved Transmittance/Absorbance Measurement System

Extend the scope of your CIMPS system for material screening and examination of electro-chromic processes! For this purpose CIMPS is equipped with a UV-VIS-IR spectrometer, two photo-electrochemical cells PECC-2 mounted on an automatic slide (one for the measuring object and one as reference), and a high-power intensity controlled white light illuminator (LED emitter or Tungsten lamp, others like D_2 or Xenon lamp on request). Automatic spectra series are measured vs. cell voltage, current and time. The list of series parameters may be optionally extended to any physical quantity supported, such as temperature, concentration, pH and more. In addition to automatic triggering, each recording can be started manually after setting the electrochemical parameters. The Thales software provides versatile light spectra analysis routines which allow many useful graphic representations, zoom-, cursor-, documentation- and data export functions. Like with all Thales data file types, Windows® detects the light spectra files automatically and presents info-boxes and graphic preview.

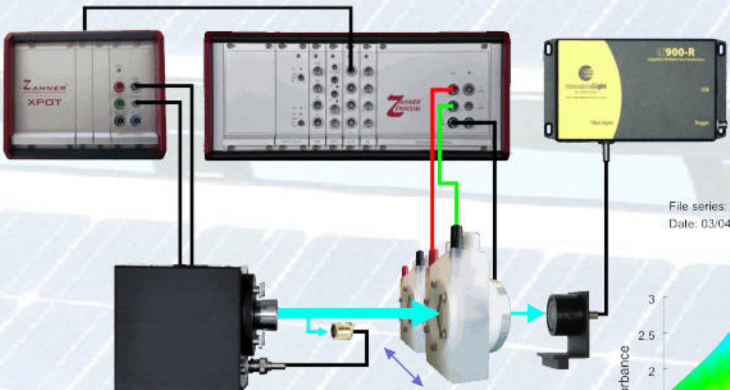
Additional Methods

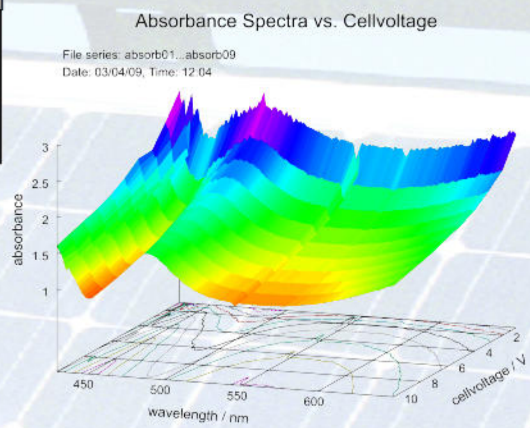
- absorbance spectra vs. voltage
- absorbance spectra vs. current
- absorbance spectra vs. time
- user script controlled absorbance spectra series

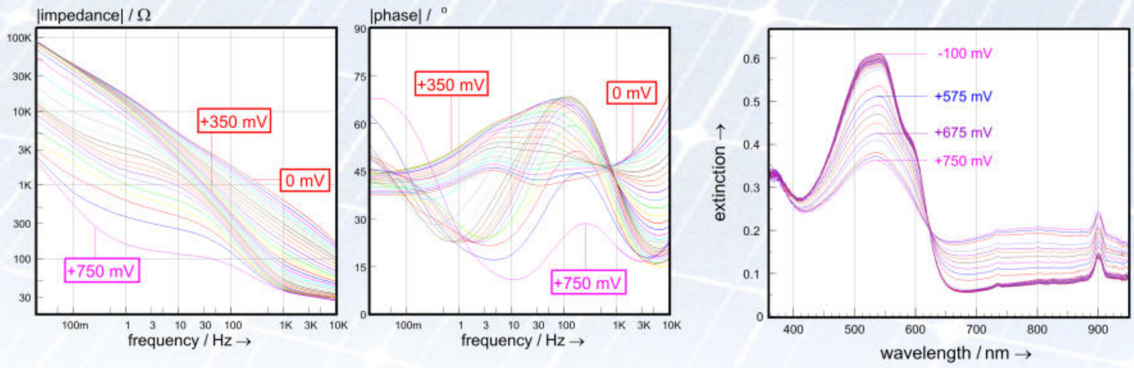
Requirements: Basic CIMPS system

abs option consist of

Two photo-electrochemical cells PECC-2
UV-VIS-IR spectrometer
Tungsten lamp or high-power white LED
D or Xenon lamp on request







P3HT-PEDOT:PSS Film Synchronous Impedance/Phase Spectra and Film Extinction Spectra vs. Cell Voltage

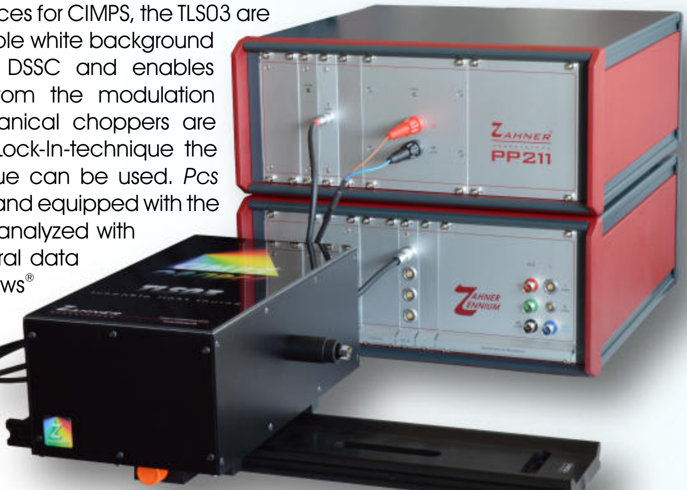
ZAHNER CIMPS

spectro-electrochemical option pcs

Photo Current Spectra: pcs

Electrochemical Photo Current Spectra (PCS) System

Equipped with the tuneable light source TLS03, one of the core applications of *pcs* is measuring the Photo Current Spectra PCS, Quantum Efficiency QE or Incident Photon Conversion Efficiency IPCE of organic and dye sensitized solar cells in the wavelength range from typical 365 nm up to 1020 nm (TLS03) with optional UV range extension, representing for the most effective range of solar light. Like the standard light sources for CIMPS, the TLS03 are based on the state-of-the-art LED technology. Switchable white background illumination helps to speed up measurements at DSSC and enables investigations on tandem solar cells. *Pcs* profits from the modulation capabilities of LEDs just as CIMPS does. No mechanical choppers are necessary and instead of the more noise-sensitive Lock-In-technique the advantages of coherent frequency analysis technique can be used. *Pcs* comes up as a plug & play application fully calibrated and equipped with the outstanding comfort of Thales: spectral data can be analyzed with the on-board package "light spectra analysis", spectral data files are covered by the preview-support of the Windows® file explorer and can be exported in manifold ways as high-quality vector graphics, bitmaps and ASCII data lists. You may view and export data, while measurements are running.



Additional Methods

- photocurrent vs. wavelength (PCS)
- quantum efficiency (QE)
- incident photon conversion efficiency (IPCE)

Requirements: Basic CIMPS system

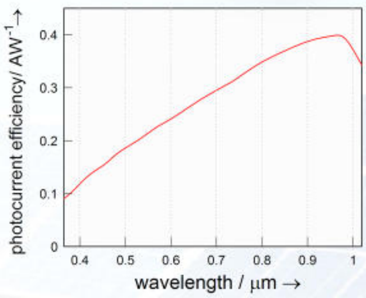
pcs option consist of

Tuneable lightsource TLS03 • 365 - 1020 nm optional UV extension (295 - 1020 nm)

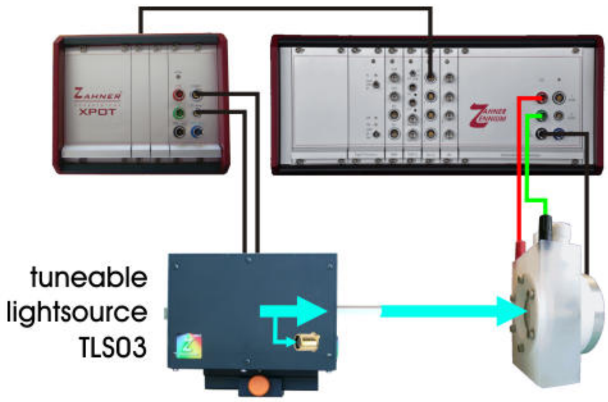
n_e: number of photoelectrons

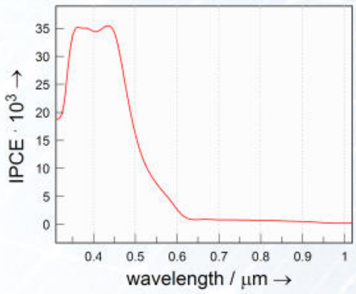
n_{ph}: number of incident photons

$$IPCE(\lambda) = \frac{n_e(\lambda)}{n_{ph}(\lambda)}$$

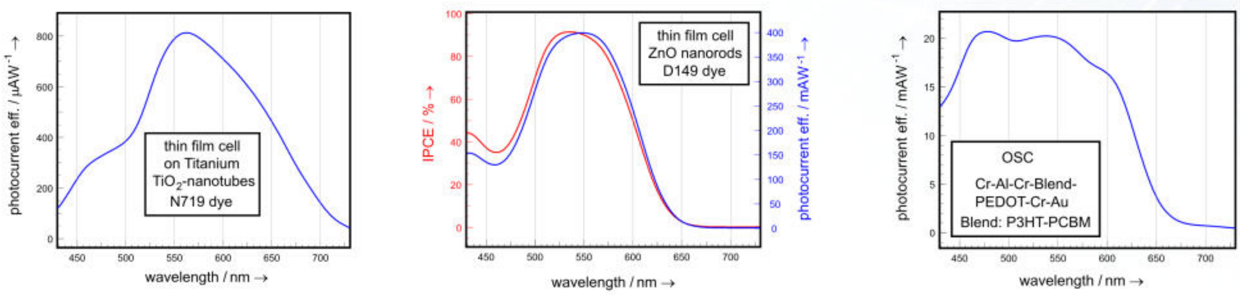


backthinned silicon photodiode





copper in aq. sodium acetate at pH 8.4
(measured with UV extension)

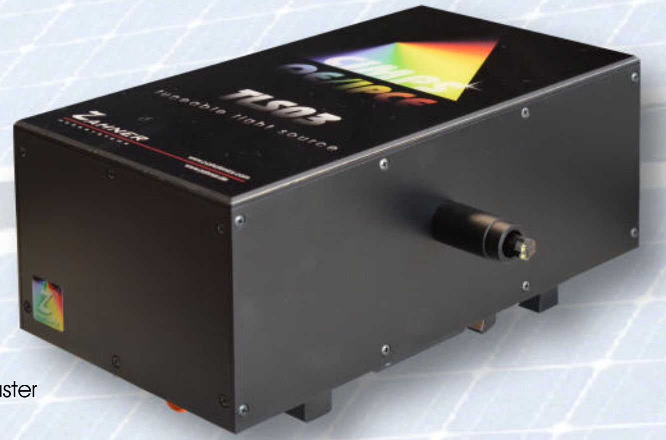


Examples for Photocurrent Spectra and Incident Photon Conversion Efficiency Spectra of Solar Cells

ZAHNER CIMPS

tuneable light source TLS03

Tuneable Light Source: TLS03



Tuneable Optical Light Source

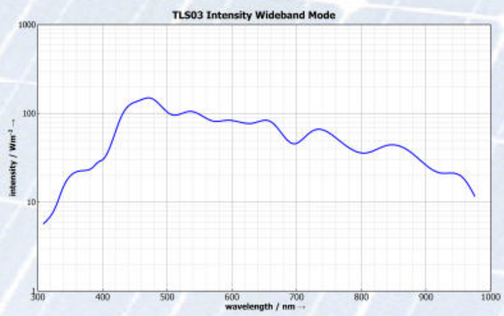
The unique and patented tuneable light-source, TLS03, uses dedicated LEDs as well as a linear monochromator. Different from systems using Xenon lamps which require filters and a mechanical chopper, the concept of the TLS03 provides high light intensity along with a low spectral half-width and a multitude of features unique for this kind of instruments. Furthermore, LEDs can be modulated much faster than a mechanical chopper can do.

Outstanding Features

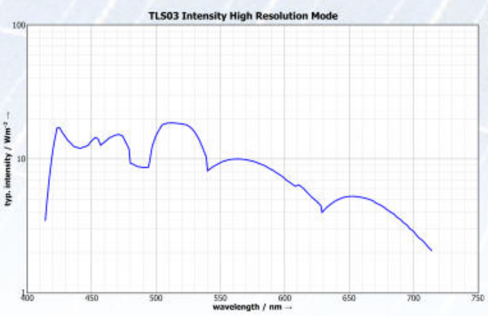
- Easy Mountable
  The optical parts are arranged on an easy mountable optical bench.
- PTB-Traceable Detector
  The integrated optical sensor (PTB-traceable, PTB is the European equivalent to NIST) is used to measure and feedback-control the light intensity exactly.
- Unique Feedback Control
  This special and exclusive feature of all Zahner CIMPS systems grants you an accurate light intensity regardless of age and temperature of the LEDs. So there is no need for a reference cell and time consuming realignments of sample holders
- No warm up time
  Using state of the art LEDs not only increases power efficiency drastically, it also eliminates the long warm up times required by Xe-lamp based systems.
- Real Sine Wave Modulation
  Unlike chopper-based systems, the TLS03 can be real sine wave modulated without harmonic distortion.
- Intelligent Control
  With its intelligent control of a multitude of LEDs of different wavelengths, the TLS03 significantly outputs more power at a certain wavelength than a system consisting of a Xenon lamp plus monochromator can do. Additionally, a switchable white background illumination helps to speed up measurements at DSSC and enables investigations on tandem solar cells.
- Wavelength Range
  The TLS03 is available with a standard wavelength range of 365 nm to 1020 nm and with an extended range of 295 nm to 1020 nm.

Benefits of TLS03 Compared to Xe-Lamp-Monochromator-Chopper Arrangements

- easy light weigthed "in a box"
- high power efficiency
- no warm up time, lower noise, lower drift
- higher monochromatic light intensity
- higher modulation frequency
- real sine-wave modulation without harmonic distortion
- switchable background illumination
- PTB traceable sensor integrated
- reference cell not necessary
- no sample repositioning



Typical light intensity of TLS03 wideband mode (with UV extension)



Typical light intensity of TLS03 in continuos mode

ZAHNER CIMPS

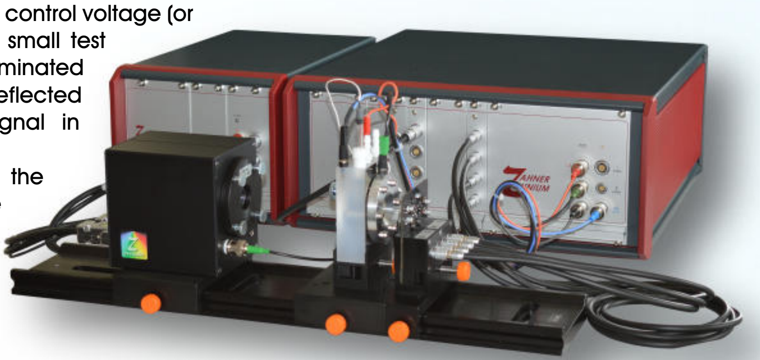
spectroelectrochemical option mdtr/ois

Dynamic Transmittance / Reflectance Measurements (OIS)

Dynamic Transmittance / Reflectance (OIS) Measurement System

Exceptional feature: assigns kinetic information unequivocally to certain colored species in a reaction chain!

Some physical systems change their optical properties under the influence of an electrical voltage or current applied. Such behavior is of high scientific interest and already reached great economic importance in the fields of electronic displays, smart windows and electronic newspapers, acting as electro-chromic devices.
The electrical control of the absorbance may have influence on the spectral properties of such systems. Dependent on the state, color or tone may change. This can be investigated with traditional absorption spectroscopy by means of CIMPS-abs.
For many applications, besides color aspects, the dynamic properties are of high importance as well. The switching time, very important for instance for displays and modulators, or the reaction time of smart windows is determined by the kinetic processes of transport- and redox-reactions or by the structural re-organization which cause the optical changes.
Dynamic Transmittance Reflectance "DTR" transfer function analysis, also known as OIS (Optical Impedance Spectroscopy), follows the ideas popular in Electrochemical Impedance Spectroscopy EIS. The basic transfer function in EIS is given between voltage and current. Like for EIS, in DTR a bias control voltage (or current) applied to the sample is modulated with a small test signal amplitude. Differing from EIS, the sample is illuminated using a certain static intensity P, and the transmitted or reflected light P^* is recorded and treated as response signal in dependence of the electrical excitation.
The dynamic transfer function DTR is calculated as the quotient between the response modulation signal (the relative intensity change in time $P^*/P = TR^*$) and the excitation signal (Voltage U^* or current I^*, dependent on the selected mode, potentiostatic or galvanostatic).

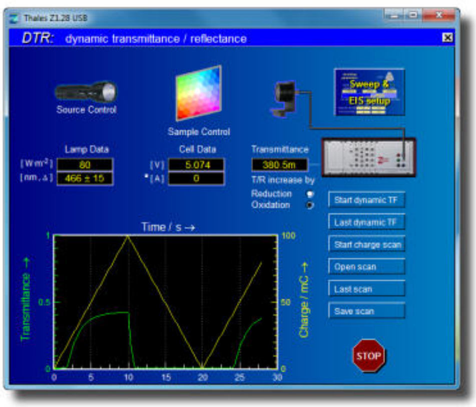


$$DTR_{pot} = \frac{\hat{T}R}{\hat{U}} \cdot e^{j\varphi}, \ [DTR_{pot}] = V^{-1}$$

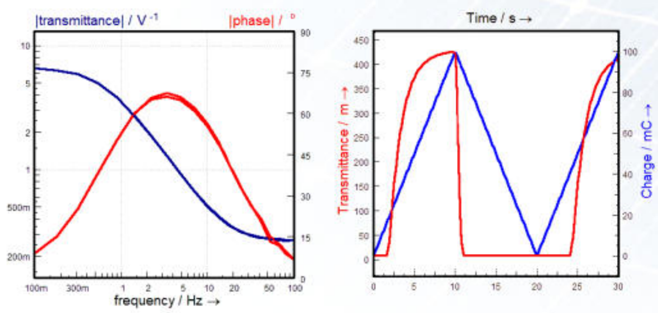
$$DTR_{gal} = \frac{\hat{T}R}{\hat{I}} \cdot e^{j\varphi}, \ [DTR_{gal}] = A^{-1}$$

j = imaginary unit
φ = phase shift $[rad]$
$\hat{}$ = amplitude symbol

DTR spectra can be understood and modelled like EIS. Time constants can be extracted and assigned to certain charge transfer, relaxation and transport processes. Their characteristic shape and phase angle helps to distinguish between them. It is known, that EIS suffers from the ambiguity of the spectra: different mechanisms may lead to identical dynamic transfer functions. It is an exceptional property of DTR that the response function can be assigned unequivocally to a certain colored species. In combination with EIS, DTR may help to cancel out further ambiguities, like it can be done also in combination with IMPS/IMVS data. The main application of CMPS-mdtr/ois is measuring frequency spectra similar to EIS belonging to a certain bias state of the system. Besides, CIMPS-mdtr/ois supports slow, quasi-static scan features determining the steady state characteristics. In order to characterize the static transmittance-reflectance behavior in dependence of the applied voltage, the sample voltage can be swept linearly between two limiting voltages under potentiostatic control. In galvanostatic mode the transmittance/reflectance-characteristic recording is displayed in form of a charge scan.



MDTR/OIS software package running voltage scan



Dynamic DTR vs. frequency and static DTR vs. charge of an LCD modulator at 2.3 V

ZAHNER CIMPS

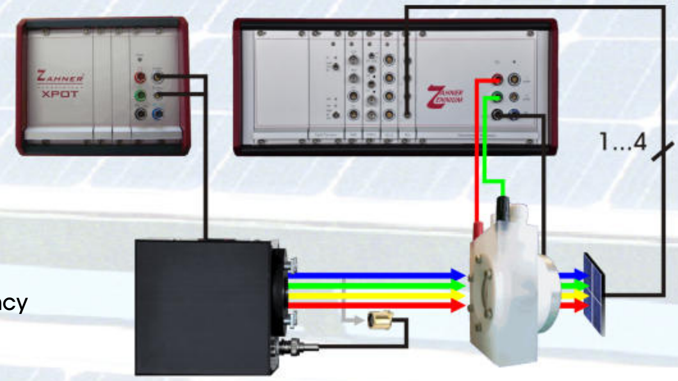
spectro-electrochemical option mdtr/ois

Multi Spectral DTR/OIS Option: mdtr/ois

Synchronous Multi Spectral Dynamic Transmittance/Reflectance with Parallel Impedance Measurement System (OIS)

Focus on up to four selective colored species in a reaction chain and determine the kinetics!

Mdtr/ois is able to acquire the DTR-spectra of more than one species in a system under test synchronously with recording an impedance spectrum. For that purpose the CIMPS instrument is extended with the multichannel synchronous AD-converter PAD4.
The transmitted/reflected light is fed through a multi channel photo-detector, providing wavelength bands in UV/IR and two selective bands in VIS. Four individual photo-amplifiers feed the detector signals to the inlets of the PAD4.
By default *mdtr/ois* works with a white high-power LED light source WLR02. A programmable multi-spectral light source MLS is optional. The emission of the MLS can be set to UV (365nm), violet (420nm), blue (445nm), green (535nm), red (630nm), NIR (740nm), IR (940nm) and white. The different wavelength bands can be selected separately in any combination. In that way, selective excitation of the system under test is performed. By using both selective light emission as well as selective light detection, crosstalk is minimized.
Parallel acquisition does not only save time. The main advantage is, that the different spectra are recorded at the same time and belong therefore to the same system state. Time drift is much less critical than in the case of sequential recording.



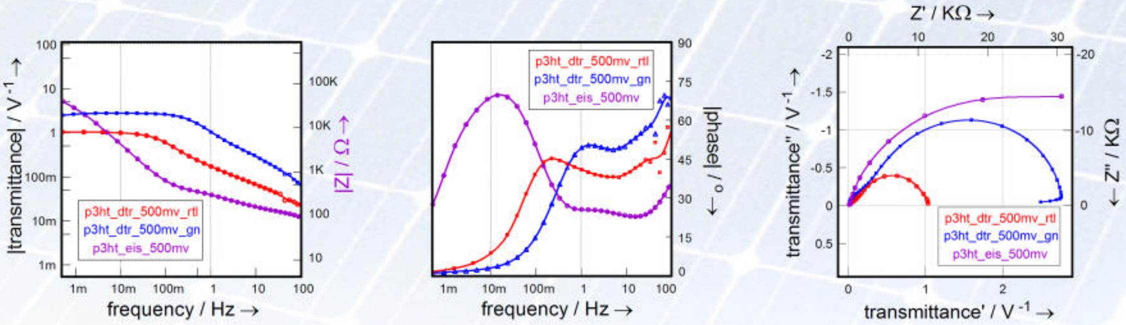
Additional Methods

- dynamic transmittance / reflectance vs. frequency
- static transmittance / reflectance vs. charge
- static transmittance / reflectance vs. voltage
- static transmittance / reflectance vs. time
- multi spectral transmittance / reflectance vs. frequency with synchronous parallel impedance

Requirements: Basic CIMPS system

mdtr/ois option consist of

PAD4 4 channel synchronous AD converter
Multi spectral sensor with amplifier
White high-power LED WLR02
Optional programmable multi spectral light source MLS



Characterization of a P3HT-PEDOT:PSS polymer multilayer with DTR and EIS at 535nm and 740nm

ZAHNER CIMPS

spectroelectrochemical option emit

Emission: emit

Photo-Electrochemical Light Emission Measurement System

Extend the scope of your CIMPS system for the examination of OPV, LED, OLED, ...
Similar to the light absorbance measurement package, this option complements CIMPS by a UV-VIS-IR spectrometer to enable spectral resolved light emission measurements. For integral emission, an additional NIST traceable calibrated photo-detector can be added. Like with CIMPS-abs, automatic spectra series measurement vs. cellvoltage, current, time can be performed and additional series parameters like temperature, voltage and pH can be used optionally. Of course, emission spectra recording can be triggered also manually while controlling the electrochemical parameters. Like for CIMPS-abs, the light spectra analysis package within Thales supports single / multi-spectra 2-D, multi-spectra 3-D and contour plot visualization for instance as emission, transmittance, absorbance, extinction in linear or logarithmic scale vs. wavelength or wave-number. Data export can be done in form of ASCII-data, as bitmap or as Windows®-EMF graphics via clipboard copy & paste or as file.

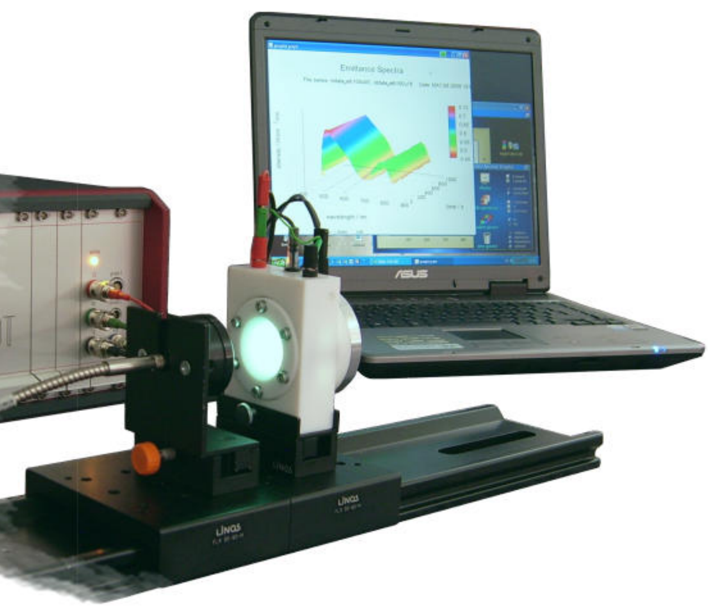
Additional Methods

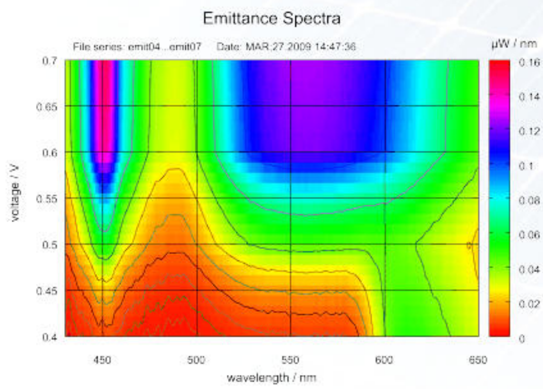
- lightemission voltage current characteristic (PVI)
- spectral resolved PVI

Requirements: Basic CIMPS system

emit option consist of

UV-VIS-IR spectrometer or NIST traceable calibrated sensor





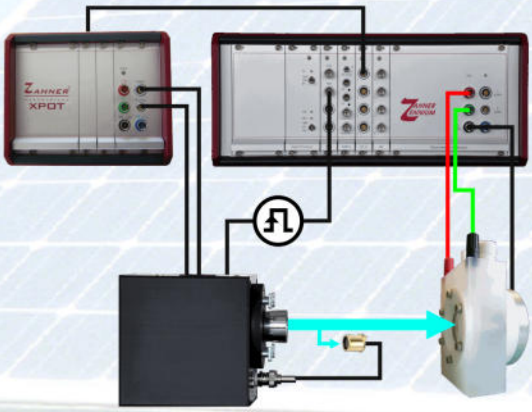
ZAHNER CIMPS

photo-electrochemical option fit

Fast Intensity Transients: fit

Fast Light Intensity Transients Measurement System

Extend the scope of your CIMPS system for the examination of fast kinetics in semiconductors, organic, dye sensitized and monolitic solar cells...
It is often advantageous, to correlate linear dynamic measurements under frequency variation like IMPS and IMVS with measurements of transient behaviour in the time domain. Slower photo-electrochemical systems, like DSSC or inorganic photo-catalytic systems can be evaluated successfully with the standard CIMPS function "Intensity Transients". For faster processes happening for instance in silicon based or other monolithic types of semiconductor solar cells, and, due to their thin layer structure also in organic solar cells, the time resolution of the standard CIMPS "Intensity Transients" is not sufficient. Photo-charge diffusion and migration time constants in such objects are too fast for a standard CIMPS system. With CIMPS-fit Zahner offers a fast intensity transients option, extending the time resolution down to 50ns.



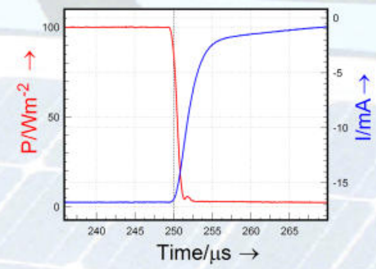
Additional Methods

- photocurrent response on fast light transients
- photovoltage response on fast light transients

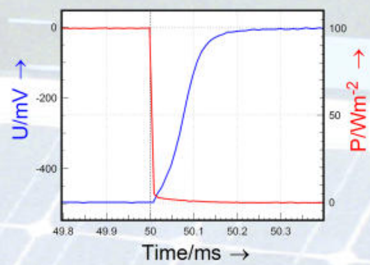
Requirements: Basic CIMPS system

fit option consist of

TR8M transient recorder Trigger cable

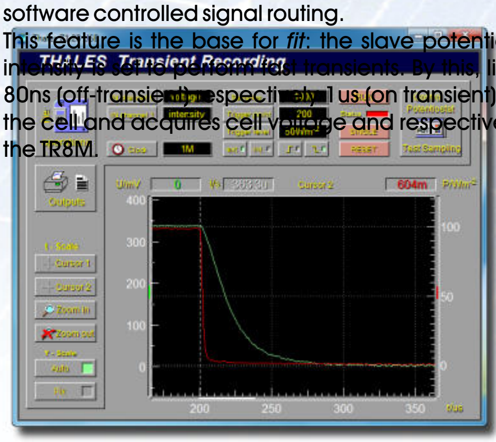


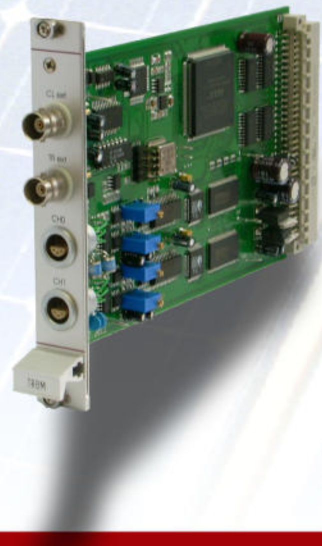
Photocurrent Transient of a Monolithic Silicon Solar Cell



Photovoltage Transient of an Organic Solar Cell (built up from Cr-Al-Cr-P3HT-PCBM-PEDOT-Cr-Au)

Fit uses the fast two-channel transient recorder TR8M plug-in from Zahner with a maximum 2-channel sampling rate of 20 MHz. The TR8M communicates with the internal potentiostat of the Zennium/IM6 and with slave potentiostats connected externally via an EPC42 by automatic, software controlled signal routing.
This feature is the base for *fit*: the slave potentiostat, active in CIMPS controlling the lightsource intensity is set to perform fast transients. By this, light switching time constants of typically less than 80ns (off-transient) respectively 1 us (on transient) can be achieved. The main potentiostat controls the cell and acquires cell voltage and respectively cell current. The signals are internally routed to the TR8M.





ZAHNER CIMPS
specifications

General

Supported Wavelength Range		user selectable (see lightsources)
Frequency Range		10 µHz - 200 kHz
Supply Output Range for LED Lightsource	PP211 XPot	±10 A / ±20 V ±0.5 A / ±25 V

CIMPS-Systems

Complete CIMPS-Systems	CIMPS-1	ZENNIUM® electrochemical workstation XPot external potentiostat, EPC42 control module, optical bench sensor, photosense-amplifier-illuminator-supply unit, dummy cell CIMPS & THALES software package
	CIMPS-2	ZENNIUM® electrochemical workstation PP211 power potentiostat, EPC42 control module, optical bench sensor, photosense-amplifier-illuminator-supply unit, dummy cell CIMPS & THALES software package
	CIMPS-3	IM6 electrochemical workstation XPot external potentiostat, EPC42 control module, optical bench sensor, photosense-amplifier-illuminator-supply unit, dummy cell CIMPS & THALES software package
	CIMPS-4	IM6 electrochemical workstation PP211 power potentiostat, EPC42 control module, optical bench sensor, photosense-amplifier-illuminator-supply unit, dummy cell CIMPS & THALES software package
	CIMPS-QE/IPCE	CIMPS-2 basic system (ZENNIUM® with PP211) qe/ipce option (TLS03 with optional UV extension) sample solar cell

Options (requires CIMPS-system)

Absorption Option	abs	two photo-electrochemical cells PECC-2, UV-VIS-IR spectrometer tungsten lamp or high power white LED
Emission Option	emit	UV-VIS-IR spectrometer or NIST traceable calibration sensor
Photo Current Spectra Option	pcs	tuneable lightsource TLS03 (UV extension optional)
Fast Intensity Transients Option	fit	TR8M transient recorder, trigger cable
Multi Spectral Dynamic Transmittance/Reflectance (OIS) Option	mdtr/ois	4 channel parallel A/D converter PAD4, high power white LED, calibrated multi sensor programmable multispectral light source MLS optional
NIST-Traceable Calibration Sensor	SEL033	for automatic calibration procedure at the customer's lab

Photo-Electrochemical Cells

	PECC-1	PECC-2
Width x Depth x Height	60 x 25 x 80 mm	60 x 25 x 80 mm
Optical Window Diameter	20 mm	18 mm
Optical Window Material	BK7 or quartz	BK7 or quartz
Working Electrode Active Diameter	max. 20 mm	max. 18 mm
Solid Material	Teflon (PTFE)	Kel-F (PCTFE)
Reference Electrode	Ag/AgCl	Ag/AgCl
Counter Electrode	Pt coil	Pt coil
Gas Inlet/Outlet	no	yes
Light Inlet	front	front and rear

Lightsources

Monochromatic	over 50 different LED lightsources wavelength range from 245 nm to 1550 nm
White	LED arrays and Tungsten lamps
Switchable and Tuneable Lightsources	wavelength range from 295 nm to 1020 nm

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Representative in your country:

specifications